Appendix B—Performance Specifications

Performance Specification 1—Specifications and test procedures for opacity continuous emission monitoring systems in stationary sources

Performance Specification 2—Specifications and test procedures for SO_2 and NO_x continuous emission monitoring systems in stationary sources

Performance Specification 3—Specifications and test procedures for O_2 and CO_2 continuous emission monitoring systems in stationary sources

Performance Specification 4—Specifications and test procedures for carbon monoxide continuous emission monitoring systems in stationary sources

Performance Specification 4A—Specifications and test procedures for carbon monoxide continuous emission monitoring systems in stationary sources

Performance Specification 5—Specifications and test procedures for TRS continuous emission monitoring systems in stationary sources

Performance Specification 6—Specifications and test procedures for continuous emission rate monitoring systems in stationary sources

Performance Specification 7—Specifications and test procedures for hydrogen sulfide continuous emission monitoring systems in stationary sources

Performance Specification 1—Specifications and Test Procedures for Opacity Continuous Emission Monitoring Systems in Stationary Sources

1. *Applicability and Principle*

1.1 Applicability. This specification contains requirements for the design, performance, and installation of instruments for opacity continuous emission monitoring systems (CEMS's) and data computation procedures for evaluating the acceptability of a CEMS. Certain design requirements and test procedures established in this specification may not apply to all instrument designs. In such instances, equivalent design requirements and test procedures may be used with prior approval of the Administrator.

Performance Specification 1 (PS 1) applies to opacity monitors installed after March 30, 1983. Opacity monitors installed before March 30, 1983, are required to comply with the provisions and requirements of PS 1 except for the following:

(a) Section 4. ''Installation Specifications.''

(b) Sections 5.1.4, 5.1.6, 5.1.7, and 5.1.8 of Section 5, ''Design and Performance Specifications.''

(c) Section 6.4 of Section 6 ''Design Specifications Verification Procedure.''

An opacity monitor installed before March 30, 1983, need not be tested to demonstrate compliance with PS 1 unless required by regulatory action other than the promulgation of PS 1. If an existing monitor is replaced with a new monitor, PS 1 shall apply except that the new monitor may be located at the old measurement location regardless of whether the location meets the requirements of Section 4. If a new measurement location is to be determined, the new location shall meet the requirements of Section 4.

1.2 Principle. The opacity of particulate matter in stack emissions is continuously monitored by a measurement system based upon the principle of transmissometry. Light having specific spectral characteristics is projected from a lamp through the effluent in the stack or duct, and the intensity of the projected light is measured by a sensor. The projected light is attenuated because of absorption and scattered by the particulate matter in the effluent; the percentage of visible light attenuated is defined as the opacity of the emission. Transparent stack emissions that do not attenuate light will have a transmittance of 100 percent or an opacity of zero percent. Opaque stack emissions that attenuate all of the visible light will have a transmittance of zero percent or an opacity of 100 percent.

This specification establishes specific design criteria for the transmissometer system. Any opacity CEMS that is expected to meet this specification is first checked to verify that the design specifications are met. Then, the opacity CEMS is calibrated, installed, and operated for a specified length of time. During this specified time period, the system is evaluated to determine conformance with the established performance specifications.

2. *Definitions*

2.1 Continuous Emission Monitoring System. The total equipment required for the determination of opacity. The system consists of the following major subsystems:

2.1.1 Sample Interface. That portion of CEMS that protects the analyzer from the effects of the stack effluent and aids in keeping the optical surfaces clean.

2.1.2 Analyzer. That portion of the CEMS that senses the pollutant and generates an output that is a function of the opacity.

2.1.3 Data Recorder. That portion of the CEMS that provides a permanent record of the analyzer output in terms of opacity. The data recorder may include automatic data-reduction capabilities.

2.2 Transmissometer. That portion of the CEMS that includes the sample interface and the analyzer.

2.3 Transmittance. The fraction of incident light that is transmitted through an optical medium.

2.4 Opacity. The fraction of incident light that is attenuated by an optical medium. Opacity (Op) and transmittance (Tr) are related by: $Op=1 \cdot Tr$.

2.5 Optical Density. A logarithmic measure of the amount of incident light attenuated. Optical density (D) is related to the transmittance and opacity as follows:

$D= \cdot \log_{10} Tr= \cdot \log_{10} (1-Op)$.

2.6 Peak Spectral Response. The wavelength of maximum sensitivity of the transmissometer.

2.7 Mean Spectral Response. The wavelength that is the arithmetic mean value of the wavelength distribution for the effective spectral response curve of the transmissometer.

2.8 Angle of View. The angle that contains all of the radiation detected by the photodetector assembly of the analyzer at a level greater than 2.5 percent of the peak detector response.

2.9 Angle of Projection. The angle that contains all of the radiation projected from the lamp assembly of the analyzer at a level of greater than 2.5 percent of the peak illuminance.

2.10 Span Value. The opacity value at which the CEMS is set to produce the maximum data display output as specified in the applicable subpart.

2.11 Upscale Calibration Value. The opacity value at which a calibration check of the CEMS is performed by simulating an upscale opacity condition as viewed by the receiver.

2.12 Calibration Error. The difference between the opacity values indicated by the CEMS and the known values of a series of calibration attenuators (filters or screens).

2.13 Zero Drift. The difference in the CEMS output readings from the zero calibration value after a stated period of normal continuous operation during which no unscheduled maintenance, repair, or adjustment took place. A calibration value of 10 percent opacity or less may be used in place of the zero calibration value.

2.14 Calibration Drift. The difference in the CEMS output readings from the upscale calibration value after a stated period of normal continuous operation during which no unscheduled maintenance, repair, or adjustment took place.

2.15 Response Time. The amount of time it takes the CEMS to display on the data recorder 95 percent of a step change in opacity.

2.16 Conditioning Period. A period of time (168 hours minimum) during which the CEMS is operated without any unscheduled maintenance, repair, or adjustment prior to initiation of the operational test period.

2.17 Operational Test Period. A period of time (168 hours) during which the CEMS is expected to operate within the established performance specifications without any unscheduled maintenance, repair, or adjustment.

2.18 Path Length. The depth of effluent in the light beam between the receiver and the transmitter of a single-pass transmissometer, or the depth of effluent between the transceiver and reflector of a double-pass transmissometer. Two path lengths are referenced by this specification as follows:

2.18.1 Monitor Path Length. The path length (depth of effluent) at the installed location of the CEMS.

2.18.2 Emission Outlet Path Length. The path length (depth of effluent) at the location where emissions are released to the atmosphere. For noncircular outlets, $D_e=(2LW)\div(L+W)$, where L is the length of the outlet and W is the width of the outlet. Note that this definition does not apply to pressure baghouse outlets with multiple stacks, side discharge vents, ridge roof monitors, etc.

3. *Apparatus*

3.1 Opacity Continuous Emission Monitoring System. Any opacity CEMS that is expected to meet the design and performance specifications in Section 5 and a suitable data recorder, such as an analog strip chart recorder or other suitable device (e.g., digital computer) with an input signal range compatible with the analyzer output.

3.2 Calibration Attenuators. Minimum of three. These attenuators must be optical filters or screens with neutral spectral characteristics selected and calibrated according to the procedures in Sections 7.1.2 and 7.1.3, and of sufficient size to attenuate the entire light beam received by the detector of the transmissometer.

3.3 Upscale Calibration Value Attenuator. An optical filter with neutral spectral characteristics, a screen, or other device that produces an opacity value (corrected for path length, if necessary) that is greater than or equal to the applicable opacity standard but less than or equal to one-half the applicable instrument span value.

3.4 Calibration Spectrophotometer. A laboratory spectrophotometer meeting the following minimum design specifications:

Parameter	Specification
Wavelength range	400–700 nm.
Detector angle of view	<10°.
Accuracy	<0.5 percent transmittance, NBS traceable calibration.

4. *Installation Specifications*

Install the CEMS at a location where the opacity measurements are representative of the total emissions from the affected facility. These requirements can be met as follows:

4.1 Measurement Location. Select a measurement location that is (a) downstream from all particulate control equipment, (b) where condensed water vapor is not present, (c) free of interference from ambient light (applicable only if transmissometer is responsive to ambient light), and (d) accessible in order to permit routine maintenance. Accessibility is an important criterion because easy access for lens cleaning, alignment checks, calibration checks, and blower maintenance will help assure quality data.

4.2 Measurement Path. The primary concern in locating a transmissometer is determining a location of well-mixed stack gas. Two factors contribute to complete mixing of emission gases: turbulence and sufficient mixing time. The criteria listed below define conditions under which well-mixed emissions can be expected.

Select a measurement path that passes through a centroidal area equal to 25 percent of the cross section. Additional requirements or modifications must be met for certain locations as follows:

4.2.1 If the location is in a straight vertical section of stack or duct and is less than 4 equivalent diameters downstream from a bend, use a path that is in the plane defined by the upstream bend (see Figure 1–1).

4.2.2 If the location is in a straight vertical section of stack or duct and is less than 4 equivalent diameters upstream from a bend, use a path that is in the plane defined by the bend (see Figure 1–2).

Pt. 60, App. B, Spec. 1

Insertillus.0035

Insertillus.0036

4.2.3 If the location is in a straight vertical section of stack or duct and is less than 4 diameters downstream and is also less than 1 diameter upstream from a bend, use a path in the plane defined by the upstream bend (see Figure 1–3).

4.2.4 If the location is in a horizontal section of duct and is at least 4 diameters downstream from a vertical bend, use a path in the horizontal plane that is between one-third and one-half the distance up the vertical axis from the bottom of the duct (see Figure 1–4).

4.2.5 If the location is in a horizontal section of duct and is less than 4 diameters downstream from a vertical bend, use a path in the horizontal plane that is between one-half and two-thirds the distance up the vertical axis from the bottom of the duct for upward flow in the vertical section, and is between one-third and one-half the distance up the vertical axis from the bottom of the duct for downward flow (Figure 1–5).

4.3 Alternative Locations and Measurement Paths. Other locations and measurement paths may be selected by demonstrating to the Administrator that the average opacity measured at the alternative location or path is equivalent to the opacity as measured at a location meeting the criteria of Sections 4.1 and 4.2. The opacity at the alternative location is considered equivalent if the average value measured at the alternative location is within the range defined by the average measured opacity ±10 percent at the location meeting the installation criteria in Section 4.2, or if the difference between the two average opacity values is less than 2 percent opacity. To conduct this demonstration, measure the opacities at the two locations or paths for a minimum period of 2 hours and compare the results. The opacities of the two locations or paths may be measured at different times, but must be measured at the same process operating conditions. Alternative procedures for determining acceptable locations may be used if approved by the Administrator.

Insertillus.0021

Pt. 60, App. B, Spec. 1

Insert illus. 0 022

Insert illus. 0 023

5. *Design and Performance Specifications*

5.1 Design Specifications. The CEMS for opacity shall comply with the following design specifications:

5.1.1 Peak and Mean Spectral Responses. The peak and mean spectral responses must occur between 500 nm and 600 nm. The response at any wavelength below 400 nm or above 700 nm shall be less than 10 percent of the peak spectral response.

5.1.2 Angle of View. The total angle of view shall be no greater than 5 degrees.

5.1.3 Angle of Projection. The total angle of projection shall be no greater than 5 degrees.

5.1.4 Optical Alignment Sight. Each analyzer must provide some method for visually determining that the instrument is optically aligned. The method provided must be capable of indicating that the unit is misaligned when an error of +2 percent opacity occurs due to misalignment at a monitor path length of 8 meters. Instruments that are capable of providing an absolute zero check while in operation on a stack or duct with effluent present, and while maintaining the same optical alignment during measurement and calibration, need not meet this requirement (e.g., some ''zero pipe'' units).

5.1.5 Simulated Zero and Upscale Calibration System. Each analyzer must include a calibration system for simulating a zero (or no greater than 10 percent) opacity and an upscale opacity value for the purpose of performing periodic checks of the transmissometer calibration while on an operating stack or duct. This calibration system will provide, as a minimum, a system check of the analyzer internal optics and all electronic circuitry including the lamp and photodetector assembly.

5.1.6 Access to External Optics. Each analyzer must provide a means of access to the optical surfaces exposed to the effluent stream in order to permit the surfaces to be cleaned without requiring removal of the unit from the source mounting or without requiring optical realignment of the unit.

5.1.7 Automatic Zero Compensation Indicator. If the CEMS has a feature that provides automatic zero compensation for dirt accumulation on exposed optical surfaces, the system must also provide some means of indicating when a compensation of 4 percent opacity has been exceeded. This indicator shall be at a location accessible to the operator (e.g., the data output terminal). During the operational test period, the system must provide some means (manual or automated) for determining the actual amount of zero compensation at the specified 24-hour intervals so that the actual 24-hour zero drift can be determined (see Section 7.4.1).

5.1.8 Slotted Tube. For transmissometers that use slotted tubes, the length of the slotted portion(s) must be equal to or greater than 90 percent of the effluent path length (distance between duct or stack walls). The slotted tube must be of sufficient size and orientation so as not to interfere with the free flow of effluent through the entire optical volume of the transmissometer photodetector. The manufacturer must also show that the transmissometer minimizes light reflections. As a minimum, this demonstration shall consist of laboratory operation of the transmissometer both with and without the slotted tube in position.

Should the operator desire to use a slotted tube design with a slotted portion equal to or less than 90 percent of the monitor path length, the operator must demonstrate to the Administrator that acceptable results can be obtained. As a minimum demonstration, the effluent opacity shall be measured using both the slotted tube instrument and another instrument meeting the requirement of this specification but not of the slotted tube design. The measurements must be made at the same location and at the same process operating conditions for a minimum period of 2 hours with each instrument. The shorter slotted tube may be used if the average opacity measured is equivalent to the opacity measured by the nonslotted tube design. The average opacity measured is equivalent if it is within the opacity range defined by the average opacity value ±10 percent measured by the nonslotted tube design, or if the difference between the average opacities is less than 2 percent opacity.

5.1.9 External Calibration Filter Access (optional). Provisions in the design of the transmissometer to accommodate an external calibration filter assembly are recommended. An adequate design would permit occasional use of external (i.e., not intrinsic to the instrument) neutral density filters to assess monitor operation.

5.2 Performance Specifications. The opacity CEMS specifications are listed in Table 1–1.

6. *Design Specifications Verification Procedure*

These procedures will not apply to all instrument designs and will require modification in some cases; all procedural modifications are subject to the approval of the Administrator.

Test each analyzer for conformance with the design specifications of Sections 5.1.1–5.1.4, or obtain a certificate of conformance from the analyzer manufacturer as follows:

6.1 Spectral Response. Obtain detector response, lamp emissivity, and filter transmittance data for the components used in the measurement system from their respective manufacturers, and develop the effective spectral response curve of the transmissometer. Then determine and report the peak spectral response wavelength, the mean spectral response wavelength, and the maximum response at any wavelength below 400 nm and above 700 nm expressed as a percentage of the peak response.

Alternatively, conduct a laboratory measurement of the instrument's spectral response curve. The procedures of this laboratory evaluation are subject to approval of the Administrator.

TABLE 1–1—PERFORMANCE SPECIFICATIONS

Parameter	Specifications
1. Calibration error [a]	≤3 percent opacity.
2. Response time	≤10 seconds.
3. Conditioning period [b]	≤168 hours.
4. Operational test period [b]	≤168 hours.
5. Zero drift (24-hour) [a]	≤2 percent opacity.
6. Calibration drift (24-hour) [a]	≤2 percent opacity.
7. Data recorder resolution	≤0.5 percent opacity.

[a] Expressed as the sum of the absolute value of the mean and the absolute value of the confidence coefficient.

[b] During the conditioning and operational test periods, the CEMS must not require any corrective maintenance, repair, replacement, or adjustment other than that clearly specified as routine and required in the operation and maintenance manuals.

6.2 Angle of View. Set up the receiver as specified by the manufacturer's written instructions. Draw an arc with radius of 3 meters in the horizontal direction. Using a small (less than 3 centimeters) nondirectional light source, measure the receiver response at 5-centimeter intervals on the arc for 30 centimeters on either side of the detector centerline. Repeat the test in the vertical direction. Then for both the horizontal and vertical directions, calculate the response of the receiver as a function of viewing angle (26 centimeters of arc with a radius of 3 meters equals 5 degrees), report relative angle of view curves, and determine and report the angle of view.

6.3 Angle of Projection. Set up the projector as specified by the manufacturer's written instructions. Draw an arc with a radius of 3 meters in the horizontal direction. Using a small (less than 3 centimeters) photoelectric light detector, measure the light intensity at 5-centimeter intervals on the arc for 30 centimeters on either side of the light source centerline of projection. Repeat the test in the vertical direction. Then for both the horizontal and vertical directions, calculate the response of the photoelectric detector as a function of the projection angle (26 centimeters of arc with a radius of 3 meters equals 5 degrees), report the relative angle of projection curves, and determine and report the angle of projection.

6.4 Optical Alignment Sight. In the laboratory set the instrument up as specified by the manufacturer's written instructions for a monitor path length of 8 meters. Align, zero, and span the instrument. Insert an attenuator of 10 percent (nominal opacity) into the instrument path length. Slowly misalign the projector unit by rotating it until a positive or negative shift of 2 percent opacity is obtained by the data recorder. Then, following the manufacturer's written instructions, check the alignment. The alignment procedure must indicate that the instrument is misaligned. Repeat this test for lateral misalignment of the projector. Realign the instrument and follow the same procedure for checking misalignment of the receiver or retroreflector unit (lateral misalignment only).

6.5 Manufacturer's Certificate of Conformance (alternative to above). Obtain from the manufacturer a certificate of conformance stating that the first analyzer randomly sampled from each month's production was tested according to Sections 6.1 through 6.4 and satisfactorily met all requirements of Section 5 of this specification. If any of the requirements were not met, the certificate must state that the entire month's analyzer production was resampled according to the military standard 105D sampling procedure (MIL–STD–105D) inspection level II; was retested for each of the applicable requirements under Section 5 of this specification; and was determined to be acceptable under MIL–STD–105D procedures, acceptable quality level 1.0. The certificate of conformance must include the results of each test performed for the analyzer(s) sampled during the month the analyzer being installed was produced.

7. *Performance Specification Verification Procedure*

Test each CEMS that conforms to the design specifications (Section 5.1) using the following procedures to determine conformance with the specifications of Table 1–1. These tests are to be performed using the data recording system to be employed during monitoring. Prior approval from the Administrator is required if different data recording systems are used during the performance test and monitoring.

7.1 Preliminary Adjustments and Tests. Before installing the system on the stack, perform these steps or tests at the affected facility or in the manufacturer's laboratory.

7.1.1 Equipment Preparation. Set up and calibrate the CEMS for the monitor path length to be used in the installation as specified by the manufacturer's written instructions. For this specification, the mounting distance between the transmitter and receiver/reflector unit at the source must be measured prior to performing the calibrations (do not use distances from engineering drawings). If the CEMS has automatic path length adjustment, follow the manufacturer's instructions to adjust the signal output from the analyzer in order to yield results based on the emission outlet path length. Set the instrument and data recording system ranges so that maximum instrument output is within the span range specified in the applicable subpart.

Align the instrument so that maximum system response is obtained during a zero (or upscale) check performed across the simulated monitor path length. As part of this alignment, include rotating the reflector unit (detector unit for single pass instruments) on its axis until the point of maximum instrument response is obtained.

Follow the manufacturer's instructions to zero and span the instrument. Perform the zero alignment adjustment by balancing the response of the CEMS so that the simulated zero check coincides with the actual zero check performed across the simulated monitor path length. At this time, measure and record the indicated upscale calibration value. The calibration value reading must be within the required opacity range (Section 3.3).

7.1.2 Calibration Attenuator Selection. Based on the span value specified in the applicable subpart, select a minimum of three calibration attenuators (low, mid, and high range) using Table 1–2.

If the system is operating with automatic path length compensation, calculate the attenuator values required to obtain a system response equivalent to the applicable values shown in Table 1–2; use Equation 1–1 for the conversion. A series of filters with nominal optical density (opacity) values of 0.1(20), 0.2(37), 0.3(50), 0.4(60), 0.5(68), 0.6(75), 0.7(80), 0.8(84), 0.9(88), and 1.0(90) are commercially available. Within this limitation of filter availability, select the calibration attenuators having the values given in Table 1–2 or having values closest to those calculated by Equation 1–1.

$$D_1 = D_2 \ (L_1/L_2) \qquad \text{Eq. 1–1}$$

TABLE 1–2—REQUIRED CALIBRATION ATTENUATOR VALUES (NOMINAL)

Span value (percent opacity)	Calibrated attenuator optical density (equivalent opacity in parenthesis)—D_2		
	Low-range	Mid-range	High-range
40	0.05 (11)	0.1 (20)	0.2 (37)
50	0.1 (20)	0.2 (37)	0.3 (50)
60	0.1 (20)	0.2 (37)	0.3 (50)
70	0.1 (20)	0.3 (50)	0.4 (60)
80	0.1 (20)	0.3 (50)	0.6 (75)
90	0.1 (20)	0.4 (60)	0.7 (80)
100	0.1 (20)	0.4 (60)	0.9 (87.5)

Where:

D_1=Nominal optical density value of required mid, low, or high range calibration attenuators.

D_2=Desired attenuator optical density output value from Table 1–2 at the span required by the applicable subpart.

L_1=Monitor path length.
L_2=Emission outlet path length.

7.1.3 Attenuator Calibration. Select a laboratory calibration spectrophotometer meeting the specifications of Section 3.4. Using this calibration spectrophotometer, calibrate the required filters or screens. Make measurements at wavelength intervals of 20 nm or less. As an alternative procedure, use the calibration spectrophotometer to measure the C.I.E. Daylight$_C$ luminous transmittance of the attenuators. Check the attenuators several times, at different locations on the attenuator.

The attenuator manufacturer must specify the period of time over which the attenuator values can be considered stable, as well as any special handling and storing procedures required to enhance attenuator stability. To assure stability, recheck attenuator values at intervals less than or equal to the period stability guaranteed by the manufacturer. Recheck at least every 3 months. If desired, perform the stability checks with an instrument (secondary) other than the calibration spectrophotometer. This secondary instrument must be a high-quality laboratory transmissometer or spectrophotometer, and the same instrument must always be used for the stability checks. If a secondary instrument is to be used for stability checks, the value of the calibrated attenuator must be measured on this secondary instrument immediately following initial calibration. If over a period of time an attenuator value changes by more than ±2 percent opacity, recalibrate the attenuator on the calibration spectrophotometer or replace it with a new attenuator.

If this procedure is conducted by the filter or screen manufacturer or by an independent laboratory, obtain a statement certifying the values and certifying that the specified procedure, or equivalent, is used.

7.1.4 Calibration Error Test. Insert the calibration attenuators (low, mid, and high range) in the transmissometer path at or as near the midpoint of the path as feasible. Place the attenuator in the measurement path at a point where the effluent will be measured; i.e., do not place the calibration attenuator in the instrument housing. If the instrument manufacturer recommends a procedure wherein the attenuators are placed in the instrument housing, the manufacturer must provide data showing this alternative procedure is acceptable. While inserting the attenuator, assure that the entire beam received by the detector will pass through the attenuator and that the attenuator is inserted in a manner which minimizes interference from reflected light. Make a total of five nonconsecutive readings for each filter. Record the monitoring system output readings in percent opacity (see example Figure 1–6). Then, if the path length is not adjusted by the measurement system, subtract the actual calibration attenuator value from the value indicated by the measurement system recorder for each of the 15 readings obtained. If the path length is adjusted by the measurement system, subtract the ''path adjusted'' calibration attenuator values from the values indicated by the measurement system recorder (the ''path adjusted'' calibration attenuator values are calculated using Equation 1–6 or 1–7). Calculate the arithmetic mean difference, standard deviation, and confidence coefficient of the five tests at each attenuator value using Equations 1–2, 1–3, and 1–4 (Sections 8.1–8.3). Calculate the sum of the absolute value of the mean difference and the absolute value of the confidence coefficient for each of the three test attenuators; report these three values as the calibration error.

Insert illus. 0053

7.1.5 System Response Test. Insert the high-range calibration attenuator in the transmissometer path five times, and record the time required for the system to respond to 95 percent of final zero and high-range filter values (see example Figure 1–7). Then calculate the mean time of the 10 upscale and downscale tests and report this value as the system response time.

Insertillus.0055

7.2 Preliminary Field Adjustments. Install the CEMS on the affected facility according to the manufacturer's written instructions and the specifications in Section 4, and perform the following preliminary adjustments:

7.2.1 Optical and Zero Alignment. When the facility is not in operation, optically align the light beam of the transmissometer upon the optical surface located across the duct or stack (i.e., the retroreflector or photodetector, as applicable) in accordance with the manufacturer's instructions; verify the alignment with the optical alignment sight. Under clear stack conditions, verify the zero alignment (performed in Section 7.1.1) by assuring that the monitoring system response for the simulated zero check coincides with the actual zero measured by the transmissometer across the clear stack. Adjust the zero alignment, if necessary. Then, after the affected facility has been started up and the effluent stream reaches normal operating temperature, recheck the optical alignment. If the optical alignment has shifted, realign the optics. Note: Careful consideration should be given to whether a ''clear stack'' condition exists. It is suggested that the stack be monitored and the data output (instantaneous real-time basis) be examined to determine whether fluctuations from zero opacity are occurring before a clear stack condition is assumed to exist.

7.2.2 Optical and Zero Alignment (Alternative Procedure). The procedure given in 7.2.1 is the preferred procedure and should be used whenever possible; however, if the facility is operating and a zero stack condition cannot practicably be obtained, use the zero alignment obtained during the preliminary adjustments (Section 7.1.1) before installing the transmissometer on the stack. After completing all the preliminary adjustments and tests required in Section 7.1, install the system at the source and align the optics, i.e., align the light beam from the transmissometer upon the optical surface located across the duct or stack in accordance with the manufacturer's instruction. Verify the alignment with the optical alignment sight. The zero alignment conducted in this manner must be verified and adjusted, if necessary, the first time a clear stack condition is obtained after the operation test period has been completed.

7.3 Conditioning Period. After completing the preliminary field adjustments (Section 7.2), operate the CEMS according to the manufacturer's instructions for an initial conditioning period of not less than 168 hours while the source is operating. Except during times of instrument zero and upscale calibration checks, the CEMS must analyze the effluent gas for opacity and produce a permanent record of the CEMS output. During this conditioning period there must be no unscheduled maintenance, repair, or adjustment. Conduct daily zero calibration and upscale calibration checks; and, when accumulated drift exceeds the daily operating limits, make adjustments and clean the exposed optical surfaces. The data recorder must reflect these checks and adjustments. At the end of the operational test period, verify that the instrument optical alignment is correct. If the conditioning period is interrupted because of source breakdown (record the dates and times of process shutdown), continue the 168-hour period following resumption of source operation. If the conditioning period is interrupted because of monitor failure, restart the 168-hour conditioning period when the monitor becomes operational.

7.4 Operational Test Period. After completing the conditioning period, operate the system for an additional 168-hour period. The 168-hour operational test period need not follow immediately after the 168-hour conditioning period. Except during times of instrument zero and upscale calibration checks, the CEMS must analyze the effluent gas for opacity and must produce a permanent record of the CEMS output. During this period, there will be no unscheduled maintenance, repair, or adjustment. Zero and calibration adjustments, optical surface cleaning, and optical realignment may be performed (optional) only at 24-hour intervals or at such shorter intervals as the manufacturer's written instructions specify. Automatic zero and calibration adjustments made by the CEMS without operator intervention or initiation are allowable at any time. During the operational test period, record all adjustments, realignments, and lens cleanings. If the operational test period is interrupted because of source breakdown, continue the 168-hour period following resumption of source operation. If the test period is interrupted because of monitor failure, restart the 168-hour period when the monitor becomes operational. During the operational test period, perform the following test procedures:

7.4.1 Zero Drift Test. At the outset of the 168-hour operational test period, record the initial simulated zero (or no greater than 10 percent) and upscale opacity readings (see example Figure 1–8). After each 24-hour interval, check and record the final zero reading before any optional or required cleaning and adjustment. Zero and upscale calibration adjustments, optical surface cleaning, and optical realignment may be performed only at 24-hour intervals (or at such shorter intervals as the manufacturer's written instructions specify), but are optional. However, adjustments and cleaning must be performed when the accumulated zero calibration or upscale calibration drift exceeds the 24-hour drift specification (±2 percent opacity). If no adjustments are made after the zero check, record the final zero reading as the initial zero reading for the next 24-hour period. If adjustments are made, record the zero value after adjustment as the initial zero value for the next 24-hour period. If the instrument has an automatic zero compensation feature for dirt accumulation on exposed lenses and the zero value cannot be measured before compensation is entered, then record the amount of automatic zero compensation (as opacity) for the final zero reading of each 24-hour period. (List the indicated zero values of the CEMS in parenthesis.) From the initial and final zero readings, calculate the zero drift for each 24-hour period. Then calculate the arithmetic mean, standard deviation, and confidence coefficient of the 24-hour zero drift and the 95 percent confidence interval using Equations 1–2, 1–3, and 1–4. Calculate the sum of the absolute value of the mean and the absolute value of the confidence coefficient, and report this value as the 24-hour zero drift.

Pt. 60, App. B, Spec. 1

Insert illus. 0059

7.4.2 Upscale Drift Test. At each 24-hour interval, after the zero calibration value has been checked and any optional or required adjustments have been made, check and record the simulated upscale calibration value. If no further adjustments are made to the calibration system at this time, record the final upscale calibration value as the initial upscale value for the next 24-hour period. If an instrument span adjustment is made, record the upscale value after adjustment as the initial upscale value for the next 24-hour period. From the initial and final upscale readings, calculate the upscale calibration drift for each 24-hour period. Then calculate the arithmetic mean, standard deviation, and confidence coefficient of the 24-hour calibration drift and the 95 percent confidence interval using Equations 1–2, 1–3, and 1–4. Calculate the sum of the absolute value of the mean and the absolute value of the confidence coefficient, and report this value as the 24-hour calibration drift.

8. *Equations*

8.1 Arithmetic Mean. Calculate the mean, $\bar{x}$, of a set of data as follows:

insertillus0062A

where:

n=Number of data points.

$\sum_{i=1}^{n} x_i$=Algebraic sum of the individual measurements x_i.

8.2 Standard Deviation. Calculate the standard deviation S_d as follows:

insertillus0062C

8.3 Confidence Coefficient. Calculate the 2.5 percent error confidence coefficient (one-tailed), CC, as follows:

insertillus0062D

Where:

$t_{0.975}$=t-value (see Table 1–3).

8.4 Error. Calculate the error (i.e., calibration error, zero drift, and calibration drift), Er, as follows:

insertillus0062E

TABLE 1–3—t-VALUES

n[a]	$t_{0.975}$	n[a]	$t_{0.975}$	n[a]	$t_{0.975}$
2	12.706	7	2.447	12	2.201
3	4.303	8	2.365	13	2.179
4	3.182	9	2.306	14	2.160
5	2.776	10	2.262	15	2.145
6	2.571	11	2.228	16	2.131

[a] The values in this table are already corrected for n–1 degrees of freedom. Use n equal to the number of individual values.

8.5 Conversion of Opacity Values from Monitor Path Length to Emission Outlet Path Length. When the monitor path length is different than the emission outlet path length, use either of the following equations to convert from one basis to the other (this conversion may be automatically calculated by the monitoring system):

$$\log(1-Op_2)=(L_2/L_1)\log(1-Op_1) \quad \text{(Eq. 1–6)}$$

$$D_2=(L_2/L_1)\,D_1 \quad \text{(Eq. 1–7)}$$

Where:

Op_1 = Opacity of the effluent based upon L_1.
Op_2 = Opacity of the effluent based upon L_2.
L_1 = Monitor path length.
L_2 = Emission outlet path length.
D_1 = Optical density of the effluent based upon L_1.
D_2 = Optical density of the effluent based upon L_2.

9. *Reporting*

Report the following (summarize in tabular form where appropriate).

9.1 General Information.

a. Facility being monitored.
b. Person(s) responsible for operational and conditioning test periods and affiliation.
c. Instrument manufacturer.
d. Instrument model number
e. Instrument serial number.
f. Month/year manufactured.
g. Schematic of monitoring system measurement path location.
h. Monitor pathlength, meters.
i. Emission outlet pathlength, meters.
j. System span value, percent opacity.
k. Upscale calibration value, percent opacity.
l. Calibrated Attenuator values (low, mid, and high range), percent opacity.

9.2 Design Specification Test Results.

a. Peak spectral response, nm.
b. Mean spectral response, nm.
c. Response above 700 nm, percent of peak.
d. Response below 400 nm, percent of peak.
e. Total angle of view, degrees.
f. Total angle of projection, degrees.
g. Results of optical alignment sight test.
h. Serial number, month/year of manufacturer for unit actually tested to show design conformance.

9.3 Performance Specification Test Results.

a. Calibration error, high-range, percent opacity.
b. Calibration error, mid-range, percent opacity.
c. Calibration error, low-range, percent opacity.
d. Response time, seconds.
e. 24-hour zero drift, percent opacity.
f. 24-hour calibration drift, percent opacity.
g. Lens cleanings, clock time.
h. Optical alignment adjustments, clock time.

9.4 Statements. Provide a statement that the conditioning and operational test periods were completed according to the requirements of Sections 7.3 and 7.4. In this statement, include the time periods during which the conditioning and operational test periods were conducted.

9.5 Appendix. Provide the data tabulations and calculations for the above tabulated results.

10. *Retest*

If the CEMS operates within the specified performance parameters of Table 1–1, the PS tests will be successfully concluded. If the CEMS fails one of the preliminary tests, make the necessary corrections and repeat the performance testing for the failed specification prior to conducting the operational test period. If the CEMS fails to meet the specifications for the operational test period, make the necessary corrections and repeat the operational test period; depending on the correction made, it may be necessary to repeat the design and preliminary performance tests.

11. *Bibliography*

1. Experimental Statistics. Department of Commerce. National Bureau of Standards Handbook 91. Paragraph 3–3.1.4 1963. pp. 3–31.

12. Performance Specifications for Stationary-Source Monitoring Systems for Gases and Visible Emissions. U.S. Environmental Protection Agency. Research Triangle Park, NC. EPA–650/2–74–013. January 1974.

PERFORMANCE SPECIFICATION 2—SPECIFICATIONS AND TEST PROCEDURES FOR SO_2 AND NO_x CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1. *Applicability and Principle*

1.1 Applicability. This specification is to be used for evaluating the acceptability of SO_2 and NO_x continuous emission monitoring systems (CEMS's) at the time of or soon after installation and whenever specified in the regulations. The CEMS may include, for certain stationary sources, a diluent (O_2 or CO_2) monitor.

This specification is not designed to evaluate the installed CEMS performance over an extended period of time nor does it identify specific calibration techniques and other auxiliary procedures to assess the CEMS performance. The source owner or operator, however, is responsible to properly calibrate, maintain, and operate the CEMS. To evaluate the CEMS performance, the Administrator may require, under Section 114 of the Act, the operator to conduct CEMS performance evaluations at other times besides the initial test. See § 60.13(c).

1.2 Principle. Installation and measurement location specifications, performance and equipment specifications, test procedures, and data reduction procedures are included in this specification. Reference method tests and calibration drift tests are conducted to determined conformance of the CEMS with the specification.

2. *Definitions*

2.1 Continuous Emission Monitoring System. The total equipment required for the determination of a gas concentration or emission rate. The system consists of the following major subsystems:

2.1.1 Sample Interface. That portion of the CEMS used for one or more of the following: sample acquisition, sample transportation, and sample conditioning, or protection of the monitor from the effects of the stack effluent.

2.1.2 Pollutant Analyzer. That portion of the CEMS that senses the pollutant gas and generates an output proportional to the gas concentration.

2.1.3 Diluent Analyzer (if applicable). That portion of the CEMS that senses the diluent gas (e.g., CO_2 or O_2) and generates an output proportional to the gas concentration.

2.1.4 Data Recorder. That portion of the CEMS that provides a permanent record of the analyzer output. The data recorder may include automatic data reduction capabilities.

2.2 Point CEMS. A CEMS that measures the gas concentration either at a single point or along a path equal to or less than 10 percent of the equivalent diameter of the stack or duct cross section.

2.3 Path CEMS. A CEMS that measures the gas concentration along a path greater than 10 percent of the equivalent diameter of the stack or duct cross section.

2.4 Span Value. The upper limit of a gas concentration measurement range specified for affected source categories in the applicable subpart of the regulations.

2.5 Relative Accuracy (RA). The absolute mean difference between the gas concentration or emission rate determined by the CEMS and the value determined by the RM's plus the 2.5 percent error confidence coefficient of a series of tests divided by the mean of the RM tests or the applicable emission limit.

2.6 Calibration Drift (CD). The difference in the CEMS output readings from the established reference value after a stated period of operation during which no unscheduled maintenance, repair, or adjustment took place.

2.7 Centroidal Area. A concentric area that is geometrically similar to the stack or duct cross section and is no greater than 1 percent of the stack or duct cross-sectional area.

2.8 Representative Results. As defined by the RM test procedure outlined in this specification.

3. *Installation and Measurement Location Specifications*

3.1 The CEMS Installation and Measurement Location. Install the CEMS at an accessible location where the pollutant concentration or emission rate measurements are directly representative or can be corrected so as to be representative of the total emissions from the affected facility or at the measurement location cross section. Then select representative measurement points or paths for monitoring in locations that the CEMS will pass the RA test (see Section 7). If the cause of failure to meet the RA test is determined to be the measurement location and a satisfactory correction technique cannot be established, the Administrator may require the CEMS to be relocated.

Suggested measurement locations and points or paths that are most likely to provide data that will meet the RA requirements are listed below.

3.1.1 Measurement Location. It is suggested that the measurement location be (1) at least two equivalent diameters downstream from the nearest control device, the point of pollutant generation, or other point at which a change in the pollutant concentration or emission rate may occur and (2) at least a half equivalent diameter upstream from the effluent exhaust or control device.

3.1.2 Point CEMS. It is suggested that the measurement point be (1) no less than 1.0 meter from the stack or duct wall or (2) within or centrally located over the centroidal area of the stack or duct cross section.

3.1.3 Path CEMS. It is suggested that the effective measurement path (1) be totally within the inner area bounded by a line 1.0 meter from the stack or duct wall, or (2) have at least 70 percent of the path within the inner 50 percent of the stack or duct cross-sectional area, or (3) be centrally located over any part of the centroidal area.

3.2 Reference Method (RM) Measurement Location and Traverse Points. Select, as appropriate, an accessible RM measurement point at least two equivalent diameters downstream from the nearest control device, the point of pollutant generation, or other point at which a change in the pollutant concentration or emission rate may occur, and at least a half equivalent diameter upstream from the effluent exhaust or control device. When pollutant concentration changes are due solely to diluent leakage (e.g., air heater leakages) and pollutants and diluents are simultaneously measured at the same location, a half diameter may be used in lieu of two equivalent diameters. The CEMS and RM locations need not be the same.

Then select traverse points that assure acquisition of representative samples over the stack or duct cross section. The minimum requirements are as follows: Establish a ''measurement line'' that passes through the centroidal area and in the direction of any expected stratification. If this line interferes with the CEMS measurements, displace the line up to 30 cm (or 5 percent of the equivalent diameter of the cross section, whichever is less) from the centroidal area. Locate three traverse points at 16.7, 50.0, and 83.3 percent of the measurement line. If the measurement line is longer than 2.4 meters and pollutant stratification is not expected, the tester may choose to locate the three traverse points on the line at 0.4, 1.2, and 2.0 meters from the stack or duct wall. This option must not be used after wet scrubbers or at points where two streams with different pollutant concentrations are combined. The tester may select other traverse points, provided that they can be shown to the satisfaction of the Administrator to provide a representative sample over the stack or duct cross section. Conduct all necessary RM tests within 3 cm (but no less than 3 cm from the stack or duct wall) of the traverse points.

4. *Performance and Equipment Specifications*

4.1 Data Recorder Scale. The CEMS data recorder response range must include zero and a high-level value. The high-level value is chosen by the source owner or operator and is defined as follows:

For a CEMS intended to measure an uncontrolled emission (e.g., SO_2 measurements at the inlet of a flue gas desulfurization unit), the high-level value must be between 1.25 and 2 times the average potential emission level, unless otherwise specified in an applicable subpart of the regulations. For a CEMS installed to measure controlled emissions or emissions that are in compliance with an applicable regulation, the high-level value must be between 1.5 times the pollutant concentration corresponding to the emission standard level and the span value. If a lower high-level value is used, the source must have the capability of measuring emissions which exceed the full-scale limit of the CEMS in accordance with the requirements of applicable regulations.

The data recorder output must be established so that the high-level value is read between 90 and 100 percent of the data recorder full scale. (This scale requirement may not be applicable to digital data recorders.) The calibration gas, optical filter, or cell values used to establish the data recorder scale should produce the zero and high-level values. Alternatively, a calibration gas, optical filter, or cell value between 50 and 100 percent of the high-level value may be used in place of the high-level value provided the data recorder full-scale requirements as described above are met.

The CEMS design must also allow the determination of calibration drift at the zero and high-level values. If this is not possible or practical, the design must allow these determinations to be conducted at a low-level value (zero to 20 percent of the high-level value) and at a value between 50 and 100 percent of the high-level value. In special cases, if not already approved, the Administrator may approve a single-point calibration-drift determination.

4.2 Calibration Drift. The CEMS calibration must not drift or deviate from the reference value of the gas cylinder, gas cell, or optical filter by more than 2.5 percent of the span value. If the CEMS includes pollutant and diluent monitors, the calibration drift must be determined separately for each in terms of concentrations (see PS 3 for the diluent specifications).

4.3 The CEMS RA. The RA of the CEMS must be no greater than 20 percent of the mean value of the RM test data in terms of the units of the emission standard or 10 percent of the applicable standard, whichever is greater. For SO_2 emission standards between 130 and 86 ng/J (0.30 and 0.20 lb/million Btu), use 15 percent of the applicable standard; below 86 ng/J (0.20 lb/million Btu), use 20 percent of emission standard.

5. *Performance Specification Test Procedure*

5.1 Pretest Preparation. Install the CEMS, prepare the RM test site according to the specifications in Section 3, and prepare the CEMS for operation according to the manufacturer's written instructions.

5.2 Calibration Drift Test Period. While the affected facility is operating at more than 50 percent of normal load, or as specified in an applicable subpart, determine the magnitude of the calibration drift (CD) once each day (at 24-hour intervals) for 7 consecutive days according to the procedure given in Section 6. To meet the requirement of Section 4.2, none of the CD's must exceed the specification.

5.3 RA Test Period. Conduct the RA test according to the procedure given in Section 7 while the affected facility is operating at more than 50 percent or normal load, or as specified in an applicable subpart. To meet the specifications, the RA must be equal to or less than 20 percent of the mean value of the RM test data in terms of the units of the emission standard or 10 percent of the applicable standard, whichever is greater. For instruments that use common components to measure more than one effluent gas constituent, all channels must simultaneously pass the RA requirement, unless it can be demonstrated that any adjustments made to one channel did not affect the others.

The RA test may be conducted during the CD test period.

6. *The CEMS Calibration Drift Test Procedure*

The CD measurement is to verify the ability of the CEMS to conform to the established CEMS calibration used for determining the emission concentration or emission rate. Therefore, if periodic automatic or manual adjustments are made to the CEMS zero and calibration settings, conduct the CD test immediately before these adjustments, or conduct it in such a way that the CD can be determined.

Conduct the CD test at the two points specified in Section 4.1. Introduce to the CEMS the reference gases, gas cells, or optical filters (these need not be certified). Record the CEMS response and subtract this value from the reference value (see example data sheet in Figure 2–1).

7. *Relative Accuracy Test Procedure*

7.1 Sampling Strategy for RM Tests. Conduct the RM tests in such a way that they will yield results representative of the emissions from the source and can be correlated to the CEMS data. Although it is preferable to conduct the diluent (if applicable), moisture (if needed), and pollutant measurements simultaneously, the diluent and moisture measurements that are taken within a 30- to 60-minute period, which includes the pollutant measurements, may be used to calculate dry pollutant concentration and emission rate.

In order to correlate the CEMS and RM data properly, mark the beginning and end of each RM test period of each run (including the exact time of the day) on the CEMS chart recordings or other permanent record of output. Use the following strategies for the RM tests:

7.1.1 For integrated samples, e.g., Method 6 and Method 4, make a sample traverse of at least 21 minutes, sampling for 7 minutes at each traverse point.

7.1.2 For grab samples, e.g., Method 7, take one sample at each traverse point, scheduling the grab samples so that they are taken simultaneously (within a 3-minute period) or are an equal interval of time apart over a 21-minute (or less) period. A test run for grab samples must be made up of at least three separate measurements.

NOTE: At times, CEMS RA tests are conducted during new source performance standards performance tests. In these cases, RM results obtained during CEMS RA tests may be used to determine compliance as long as the source and test conditions are consistent with the applicable regulations.

7.2 Correlation of RM and CEMS Data. Correlate the CEMS and the RM test data as to the time and duration by first determining from the CEMS final output (the one used for reporting) the integrated average pollutant concentration or emission rate for each pollutant RM test period. Consider system response time, if important, and confirm that the pair of results are on a consistent moisture, temperature, and diluent concentration basis. Then, compare each integrated CEMS value against the corresponding average RM value. Use the following guidelines to make these comparisons.

7.2.1 If the RM has an integrated sampling technique, make a direct comparison of the RM results and CEMS integrated average value.

7.2.2 If the RM has a grab sampling technique, first average the results from all grab samples taken during the test run and then compare this average value against the integrated value obtained from the CEMS chart recording or output during the run. If the pollutant concentration is varying with time over the run, the tester may choose to use the arithmetic average of the CEMS value recorded at the time of each grab sample.

7.3 Number of RM Tests. Conduct a minimum of nine sets of all necessary RM tests. Conduct each set within a period of 30 to 60 minutes.

NOTE: The tester may choose to perform more than nine sets of RM tests. If this option is chosen, the tester may, at his discretion, reject a maximum of three sets of the test results so long as the total number of test results used to determine the RA is greater than or equal to nine, but he must report all data including the rejected data.

7.4 Reference Methods. Unless otherwise specified in an applicable subpart of the regulations, Methods 3B, 4, 6, and 7, or their approved alternatives, are the reference methods for diluent (O_2 and CO_2), moisture, SO_2, and NO_x, respectively.

7.5 Calculations. Summarize the results on a data sheet. An example is shown in Figure 2–2. Calculate the mean of the RM values. Calculate the arithmetic differences between the RM and the CEMS output sets. Then calculate the mean of the difference, standard deviation, confidence coefficient, and CEMS RA, using Equations 2–1, 2–2, 2–3, and 2–4.

8. *Equations*

8.1 Arithmetic Mean. Calculate the arithmetic mean of the difference, d, of a data set as follows:

InsertIllus.1A

Where:

n=Number of data points.

InsertIllus.2A

When the mean of the differences of pairs of data is calculated, be sure to correct the data for moisture, if applicable.

8.2 Standard Deviation. Calculate the standard deviation, S_d, as follows:

InsertIllus.3A

8.3 Confidence Coefficient. Calculate the 2.5 percent error confidence coefficient (one-tailed), CC, as follows:

InsertIllus.4A

Where:

$t_{0.975}$=t-value (see Table 2–1)

TABLE 2–1—t-VALUES

n[a]	$t_{0.975}$	n[a]	$t_{0.975}$	n[a]	$t_{0.975}$
2	12.706	7	2.447	12	2.201
3	4.303	8	2.365	13	2.179
4	3.182	9	2.306	14	2.160
5	2.776	10	2.262	15	2.145
6	2.571	11	2.228	16	2.131

[a] The values in this table are already corrected for n-1 degrees of freedom. Use n equal to the number of individual values.

8.4 Relative Accuracy. Calculate the RA of a set of data as follows:

InsertIllus.5A

Where:

|d|=Absolute value of the mean of differences (from Equation 2–1).

|CC|=Absolute value of the confidence coefficient (from Equation 2–3).

RM=Average RM value or applicable standard.

9. *Reporting*

At a minimum (check with the appropriate regional office, or State, or local agency for additional requirements, if any) summarize in tabular form the results of the CD tests and the relative accuracy tests or alternative RA procedure as appropriate. Include all data sheets, calculations, charts (records of CEMS responses), cylinder gas concentration certifications, and calibration cell response certifications (if applicable), necessary to substantiate that the performance of the CEMS met the performance specifications.

10. *Alternative Procedures*

10.1 Alternative to Relative Accuracy Procedure in section 7. Paragraphs 60.13(j) (1) and (2) contain criteria for which the reference method relative accuracy may be waived and the following procedure substituted.

10.1.1 Conduct a complete CEMS status check following the manufacturer's written instructions. The check should include operation of the light source, signal receiver, timing mechanism functions, data acquisition and data reduction functions, data recorders, mechanically operated functions (mirror movements, zero pipe operation, calibration gas valve operations, etc.), sample filters, sample line heaters, moisture traps, and other related functions of the CEMS, as applicable. All parts of the CEMS shall be functioning properly before proceeding to the alternative RA procedure.

10.1.2 Challenge each monitor (both pollutant and diluent, if applicable) with cylinder gases of known concentrations or calibration cells that produce known responses at two measurement points within the following ranges:

MEASUREMENT RANGE

Measurement point	Pollutant monitor	Diluent monitor for	
		CO_2	O_2
1	20–30 percent of span value.	5–8 percent by volume.	4–6 percent by volume.
2	50–60 percent of span value.	10–14 percent by volume.	8–12 percent by volume.

Use a separate cylinder gas or calibration cell for measurement points 1 and 2. Challenge the CEMS and record the responses three times at each measurement point. Do not dilute gas from a cylinder when challenging the CEMS. Use the average of the three responses in determining relative accuracy.

Operate each monitor in its normal sampling mode as nearly as possible. When using cylinder gases, pass the cylinder gas through all filters, scrubbers, conditioners, and other monitor components used during normal sampling and as much of the sampling probe as practical. When using calibration cells, the CEMS components used in the normal sampling mode should not be by-passed during the RA determination. These include light sources, lenses, detectors, and reference cells. The CEMS should be challenged at each measurement point for a sufficient period of time to assure adsorption-desorption reactions on the CEMS surfaces have stabilized.

Use cylinder gases that have been certified by comparison to National Bureau of Standards (NBS) gaseous standard reference material (SRM) or NBS/EPA-approved gas manufacturer's certified reference material (CRM) (See Citation 2 in the Bibliography) following EPA traceability protocol Number 1 (See Citation 3 in the Bibliography). As an alternative to protocol Number 1 gases, CRM's may be used directly as alternative RA cylinder gases. A list of gas manufacturers that have prepared approved CRM's is available from EPA at the address shown in Citation 2. Procedures for preparation of CRM are described in Citation 2.

Use calibration cells certified by the manufacturer to produce a known response in the CEMS. The cell certification procedure shall include determination of CEMS response produced by the calibration cell in direct comparison with measurement of gases of known concentration. This can be accomplished using SRM or CRM gases in a laboratory source simulator or through extended tests using reference methods at the CEMS location in the exhaust stack. These procedures are discussed in Citation 4 in the Bibliography. The calibration cell certification procedure is subject to approval of the Administrator.

10.1.3 The differences between the known concentrations of the cylinder gases and the concentrations indicated by the CEMS are used to assess the accuracy of the CEMS.

The calculations and limits of acceptable relative accuracy (RA) are as follows:

(a) For pollutant CEMS:

$$RA = \left| \frac{d}{AC} \times 100 \right| \leq 15 \text{ percent}$$

Where:

d=Difference between response and the known concentration/response.

AC=The known concentration/response of the cylinder gas or calibration cell.

(b) For diluent CEMS:

RA=|d| ≤ 0.7 percent O_2 or CO_2, as applicable.

NOTE: Waiver of the relative accuracy test in favor of the alternative RA procedure does not preclude the requirements to complete the calibration drift (CD) tests nor any other requirements specified in the applicable regulation(s) for reporting CEMS data and performing CEMS drift checks or audits.

Pt. 60, App. B, Spec. 2

Insertillus.0496

Insert illus. 497

11. *Bibliography*

1. Department of Commerce. Experimental Statistics. Handbook 91. Washington, DC, p. 3–31, paragraphs 3–3.1.4.

2. ''A Procedure for Establishing Traceability of Gas Mixtures to Certain National Bureau of Standards Standard Reference Materials.'' Joint publication by NBS and EPA. EPA–600/7–81–010. Available from U.S. Environmental Protection Agency, Quality Assurance Division (MD–77), Research Triangle Park, NC 27711.

3. ''Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors. (Protocol Number 1).'' June 1978. Protocol Number 1 is included in the *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods.* EPA–600/4–77–027b. August 1977. Volume III is available from the U.S. EPA, Office of Research and Development Publications, 26 West St. Clair Street, Cincinnati, OH 45268.

4. ''Gaseous Continuous Emission Monitoring Systems—Performance Specification Guidelines for SO_2, NO_x, CO_2, O_2, and TRS.'' EPA–450/3–82–026. Available from U.S. Environmental Protection Agency, Emission Standards and Engineering Division (MD–19), Research Triangle Park, NC 27711.

PERFORMANCE SPECIFICATION 3—SPECIFICATIONS AND TEST PROCEDURES FOR O_2 AND CO_2 CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1. *Applicability and Principle*

1.1 Applicability. This specification is to be used for evaluating acceptability of O_2 and CO_2 continuous emission monitoring systems (CEM's) at the time of or soon after installation and whenever specified in an applicable subpart of the regulations. The specification applies to O_2 or CO_2 monitors that are not included under Performance Specification 2 (PS 2).

This specification is not designed to evaluate the installed CEMS performance over an extended period of time, nor does it identify specific calibration techniques and other auxiliary procedures to assess the CEMS performance. The source owner or operator, however, is responsible to calibrate, maintain, and operate the CEMS properly. To evaluate the CEMS performance, the Administrator may require, under Section 114 of the Act, the operator to conduct CEMS performance evaluations in addition to the initial test. See Section 60.13(c).

The definitions, installation and measurement location specifications, test procedures, data reduction procedures, reporting requirements, and bibliography are the same as in PS 2, Sections 2, 3, 5, 6, 8, 9, and 10, and also apply to O_2 and CO_2 CEMS's under this specification. The performance and equipment specifications and the relative accuracy (RA) test procedures for O_2 and CO_2 CEMS do not differ from those for SO_2 and NO_x CEMS, except as noted below.

1.2 Principle. Reference method (RM) tests and calibration drift tests are conducted to determine conformance of the CEMS with the specification.

2. *Performance and Equipment Specifications*

2.1 Instrument Zero and Span. This specification is the same as Section 4.1 of PS 2.

2.2 Calibration Drift. The CEMS calibration must not drift by more than 0.5 percent O_2 or CO_2 from the reference value of the gas, gas cell, or optical filter.

2.3 The CEMS RA. The RA of the CEMS must be no greater than 20 percent of the mean value of the RM test data or 1.0 percent O_2 or CO_2 , whichever is greater.

3. *Relative Accuracy Test Procedure*

3.1 Sampling Strategy for RM Tests, Correlation of RM and CEMS Data, Number of RM Tests, and Calculations. This is the same as PS 2, Sections 7.1, 7.2, 7.3, and 7.5, respectively.

3.2 Reference Method. Unless otherwise specified in an applicable subpart of the regulations, Method 3B of appendix A or any approved alternative is the RM for O_2 or CO_2.

PERFORMANCE SPECIFICATION 4—SPECIFICATIONS AND TEST PROCEDURES FOR CARBON MONOXIDE CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1. *Applicability and Principle*

1.1 Applicability. This specification is to be used for evaluating the acceptability of carbon monoxide (CO) continuous emission monitoring systems (CEMS) at the time of or soon after installation and whenever specified in an applicable subpart of the regulations.

This specification is not designed to evaluate the installed CEMS performance over an extended period of time nor does it identify specific calibration techniques and other auxiliary procedures to assess CEMS performance. The source owner or operator, however, is responsible to calibrate, maintain, and operate the CEMS. To evaluate CEMS performance, the Administrator may require, under section 114 of the Act, the source owner or operator to conduct CEMS performance evaluations at other times besides the initial test. See § 60.13(c).

The definitions, installation specifications, test procedures, data reduction procedures for determining calibration drifts (CD) and relative accuracy (RA), and reporting of Performance Specification 2 (PS 2), Sections 2, 3, 5, 6, 8, and 9 apply to this specification.

1.2 Principle. Reference method (RM), CD, and RA tests are conducted to determine that the CEMS conforms to the specification.

2. *Performance and Equipment Specifications*

2.1 Instrument Zero and Span. This specification is the same as Section 4.1 of PS 2.

2.2 Calibration Drift. The CEMS calibration must not drift or deviate from the reference value of the calibration gas, gas cell, or optical filter by more than 5 percent of the established span value for 6 out of 7 test days (e.g., the established span value is 1000 ppm for subpart J affected facilities).

2.3 Relative Accuracy. The RA of the CEMS shall be no greater than 10 percent of the mean value of the RM test data in terms of the units of the emission standard or 5 percent of the applicable standard, whichever is greater.

3. *Relative Accuracy Test Procedure*

3.1 Sampling Strategy for RM Tests, Correlation of RM and CEMS Data, Number of RM Tests, and Calculations. These are the same as PS 2, Sections 7.1, 7.2, 7.3, and 7.5, respectively.

3.2 Reference Methods. Unless otherwise specified in an applicable subpart of the regulation, Method 10 is the RM for this PS. When evaluating nondispersive infrared continuous emission analyzers, Method 10 shall use the alternative interference trap specified in section 10.1 of the method. Method 10A or 10B is an acceptable alternative to method 10.

4. *Bibliography*

1. Ferguson, B.B., R.E. Lester, and W.J. Mitchell. Field Evaluation of Carbon Monoxide and Hydrogen Sulfide Continuous Emission Monitors at an Oil Refinery. U.S. Environmental Protection Agency. Research Triangle Park, NC. Publication No. EPA–600/4–82–054. August 1982. 100 p.

2. Repp, M. Evaluation of Continuous Monitors for Carbon Monoxide in Stationary Sources. U.S. Environmental Protection Agency. Research Triangle Park, NC. Publication No. EPA–600/2–77–063. March 1977/ 155 p.

3. Smith, F., D.E. Wagoner, and R.P. Donovan. Guidelines for Development of a Quality Assurance Program: Volume VIII—Determination of CO Emissions from Stationary Sources by NDIR Spectrometry. U.S. Environmental Protection Agency. Research Triangle Park, NC. Publication No. EPA–650/4–74–005–h. February 1975. 96 p.

Performance Specification 4A—Specifications and Test Procedures For Carbon Monoxide Continuous Emission Monitoring Systems in Stationary Sources

1. Applicability and Principle

1.1 Applicability.

1.1.1 This specification is to be used for evaluating the acceptability of carbon monoxide (CO) continuous emission monitoring systems (CEMS's) at the time of or soon after installation and whenever specified in an applicable subpart of the regulations.

1.1.2 This specification is not designed to evaluate the installed CEMS performance over an extended period of time nor does it identify specific calibration techniques and other auxiliary procedures to assess CEMS performance. The source owner or operator, however, is responsible to calibrate, maintain, and operate the CEMS. To evaluate CEMS performance, the Administrator may require, under section 114 of the Act, the source owner or operator to conduct CEMS performance evaluations at other times besides the initial test. See § 60.13(c).

1.1.3 The definition, installation specifications, test procedures, data reduction procedures for determining calibration drifts (CD) and relative accuracy (RA), and reporting of Performance Specification 2 (PS 2), sections 2, 3, 5, 6, 8, and 9 apply to this specification.

1.2 Principle. Reference method (RM), CD and RA tests are conducted to determine that the CEMS conforms to the specification.

2. Performance and Equipment Specifications

2.1 Data Recorder Scale. This specification is the same as section 4.1 of PS 2. The CEMS shall be capable of measuring emission levels under normal conditions and under periods of short-duration peaks of high concentrations. This dual-range capability may be met using two separate analyzers, one for each range, or by using dual-range units which have the capability of measuring both levels with a single unit. In the latter case, when the reading goes above the full-scale measurement value of the lower range, the higher-range operation shall be started automatically. The CEMS recorder range must include zero and a high-level value.

For the low-range scale, the high-level value shall be between 1.5 times the pollutant concentration corresponding to the emission standard level and the span value. For the high-range scale, the high-level value shall be set at 2000 ppm, as a minimum, and the range shall include the level of the span value. There shall be no concentration gap between the low- and high-range scales.

2.2 Interference Check. The CEMS must be shown to be free from the effects of any interferences.

2.3 Response Time. The CEMS response time shall not exceed 1.5 min to achieve 95 percent of the final stable value.

2.4 Calibration Drift. The CEMS calibration must not drift or deviate from the reference value of the calibration gas, gas cell, or optical filter by more than 5 percent of the established span value for 6 out of 7 test days.

2.5 Relative Accuracy. The RA of the CEMS shall be no greater than 10 percent of the mean value of the RM test data in terms of the units of the emission standard or 5 ppm, whichever is greater. Under conditions where the average CO emissions are less than 10 percent of the standard, a cylinder gas audit may be performed in place of the RA test to determine compliance with these limits. In this case, the cylinder gas shall contain CO in 12 percent carbon dioxide as an interference check. If this option is exercised, Method 10 must be used to verify that emission levels are less than 10 percent of the standard.

3. Response Time Test Procedure

The response time test applies to all types of CEMS's, but will generally have significance only for extractive systems. The entire system is checked with this procedure including applicable sample extraction and transport, sample conditioning, gas analyses, and data recording.

Introduce zero gas into the system. For extractive systems, the calibration gases should be introduced at the probe as near to the sample location as possible. For in-situ systems, introduce the zero gas at the sample interface so that all components active in the analysis are tested. When the system output has stabilized (no change greater than 1 percent of full scale for 30 sec), switch to monitor stack effluent and wait for a stable value. Record the time (upscale response time) required to reach 95 percent of the final stable value. Next, introduce a high-level calibration gas and repeat the procedure (stabilize, switch the sample, stabilize, record). Repeat the entire procedure three times and determine the mean upscale and downscale response times. The slower or longer of the two means is the system response time.

4. Relative Accuracy Test Procedure

4.1 Sampling Strategy for RM Tests, Correlation of RM and CEMS Data, Number of RM Tests, and Calculations. These are the same as PS 2, sections 7.1, 7.2, 7.3, and 7.5, respectively.

4.2 Reference Methods. Unless otherwise specified in an applicable subpart of the regulation, Method 10 is the RM for this PS. When evaluating nondispersive infrared continuous emission analyzers, Method 10 shall use the alternative interference trap specified in section 10.1 of the method. Method 10A or 10B is an acceptable alternative to Method 10.

5. Bibliography

1. Same as in Performance Specification 4, section 4.
2. ''Gaseous Continuous Emission Monitoring Systems—Performance Specification Guidelines for SO_2, NO_x, CO_2, O_2, and TRS.'' EPA–450/3–82–026. U.S. Environmental Protection Agency, Technical Support Division (MD–19). Research Triangle Park, NC 27711.

PERFORMANCE SPECIFICATION 5—SPECIFICATIONS AND TEST PROCEDURES FOR TRS CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1. *Applicability and Principle*

1.1 Applicability. This specification is to be used for evaluating the acceptability of total reduced sulfur (TRS) and whenever specified in an applicable subpart of the regulations. (At present, these performance specifications do not apply to petroleum refineries, subpart J.) Sources affected by the promulgation of the specification shall be allowed 1 year beyond the promulgation date to install, operate, and test the CEMS. The CEMS's may include O_2 monitors which are subject to Performance Specification 3 (PS 3).

The definitions, installation specifications, test procedures, and data reduction procedures for determining calibration drifts (CD's) and relative accuracy (RA), and reporting of PS 2, Sections 2, 3, 4, 5, 6, 8, and 9 also apply to this specification and must be consulted. The performance and equipment specifications do not differ from PS 2 except as listed below and are included in this specification.

1.2 Principle. The CD and RA tests are conducted to determine conformance of the CEMS with the specification.

2. *Performance and Equipment Specifications*

2.1 Instrument Zero and Span. The CEMS recorder span must be set at 90 to 100 percent of recorder full-scale using a span level between 1.5 times the pollutant concentration corresponding to the emission standard level and the span value. The CEMS design shall also allow the determination of calibration at the zero level of the calibration curve. If zero calibration is not possible or is impractical, this determination may be conducted at a low level (up to 20 percent of span value) point. The components of an acceptable permeation tube system are listed on pages 87–94 of Citation 4.2 of the Bibliography.

2.2 Calibration Drift. The CEMS detector calibration must not drift or deviate from the reference value of the calibration gas by more than 5 percent (1.5 ppm) of the established span value of 30 ppm for 6 out of 7 test days. If the CEMS includes pollutant and diluent monitors, the CD must be determined separately for each in terms of concentrations (see PS 3 for the diluent specifications).

2.3 The CEMS Relative Accuracy. The RA of the CEMS shall be no greater than 20 percent of the mean value of the reference method (RM) test data in terms of the units of the emission standard or 10 percent of the applicable standard, whichever is greater.

3. *Relative Accuracy Test Procedure*

3.1 Sampling Strategy for RM Tests, Correlation of RM and CEMS Data, Number of RM Tests, and Calculations. This is the same as PS 2, Sections 7.1, 7.2, 7.3, and 7.5, respectively. Note: For Method 16, a sample is made up of at least three separate injects equally spaced over time. For Method 16A, a sample is collected for at least 1 hour.

3.2 Reference Methods. Unless otherwise specified in an applicable subpart of the regulations, Method 16, Method 16A, or other approved alternative, shall be the RM for TRS.

4. *Bibliography*

1. Department of Commerce. Experimental Statistics. National Bureau of Standards. Handbook 91. 1963. Paragraphs 3–3.1.4, p. 3–31.
2. A Guide to the Design, Maintenance and Operation of TRS Monitoring Systems. National Council for Air and Stream Improvement Technical Bulletin No. 89. September 1977.
3. Observation of Field Performance of TRS Monitors on a Kraft Recovery Furnace. National Council for Air and Stream Improvement Technical Bulletin No. 91. January 1978.

PERFORMANCE SPECIFICATION 6—SPECIFICATIONS AND TEST PROCEDURES FOR CONTINUOUS EMISSION RATE MONITORING SYSTEMS IN STATIONARY SOURCES

1. Applicability and Principle

1.1 Applicability. The applicability for this specification is the same as Section 1.1 of Performance Specification 2 (PS 2), except this specification is to be used for evaluating the acceptability of continuous emission rate monitoring systems (CERMS's). The installation and measurement location specifications, performance specification test procedure, data reduction procedures, and reporting requirements of PS 2, Section 3, 5, 8, and 9, apply to this specification.

1.2 Principle. Reference method (RM), calibration drift (CD), and relative accuracy (RA) tests are conducted to determine that the CERMS conforms to the specification.

2. Definitions

The definitions are the same as in Section 2 of PS 2, except that this specification refers to the continuous emission rate monitoring system rather than the continuous emission monitoring system. The following definitions are added:

2.1 Continuous Emission Rate Monitoring System (CERMS). The total equipment required for the determination and recording of the pollutant mass emission rate (in terms of mass per unit of time).

2.2 Flow Rate Sensor. That portion of the CERMS that senses the volumetric flow rate and generates an output proportional to flow rate. The flow rate sensor shall have provisions to check the CD for each flow rate parameter that it measures individually (e.g., velocity pressure).

3. Performance and Equipment Specifications

3.1 Data Recorder Scale. Same as Section 4.1 of PS 2.

3.2 CD. Since the CERMS includes analyzers for several measurements, the CD shall be determined separately for each analyzer in terms of its specific measurement. The calibration for each analyzer used for the measurement of flow rate except a temperature analyzer shall not drift or deviate from either of its reference values by more than 3 percent of 1.25 times the average potential absolute value for that measurement. For a temperature analyzer, the specification is 1.5 percent of 1.25 times the average potential absolute temperature. The CD specification for each analyzer for which other PS's have been established (e.g., PS 2 for SO_2 and NO_x), shall be the same as in the applicable PS.

3.3 CERMS RA. The RA of the CERMS shall be no greater than 20 percent of the mean value of the RM's test data in terms of the units of the emission standard, or 10 percent of the applicable standard, whichever is greater.

4. CD Test Procedure

The CD measurements are to verify the ability of the CERMS to conform to the established CERMS calibrations used for determining the emission rate. Therefore, if periodic automatic or manual adjustments are made to the CERMS zero and calibration settings, conduct the CD tests immediately before these adjustments, or conduct them in such a way what CD can be determined.

Conduct the CD tests for pollutant concentration at the two values specified in Section 4.1 of PS 2. For each of the other parameters that are selectively measured by the CERMS (e.g., velocity pressure), use two analogous values: one that represents zero to 20 percent of the high-level value (a value that is between 1.25 and 2 times the average potential value) for that parameter, and one that represents 50 to 100 percent of the high-level value. Introduce, or activate internally, the reference signals to the CERMS (these need not be certified). Record the CERMS response to each, and subtract this value from the respective reference value (see example data sheet in Figure 6–1).

5. RA Test Procedure

5.1 Sampling Strategy for RM's Tests, Correlation of RM and CERMS Data, Number of RM's Tests, and Calculations. These are the same as PS 2, Sections 7.1, 7.2, 7.3, and 7.5, respectively. Summarize the results on a data sheet. An example is shown in Figure 6–2. The RA test may be conducted during the CD test period.

5.2 Reference Methods (RM's). Unless otherwise specified in the applicable subpart of the regulations, the RM for the pollutant gas is the appendix A method that is cited for compliance test purposes, or its approved alternatives. Methods 2, 2A, 2B, 2C, or 2D, as applicable are the RM's for the determination of volumetric flow rate.

6. Bibliography

1. Brooks, E.F., E.C. Beder, C.A. Flegal, D.J. Luciani, and R. Williams. Continuous Measurement of Total Gas Flow Rate from Stationary Sources. U.S. Envionmental Protection Agency. Research Triangle Park, NC. Publication No. EPA–650/2–75–020. February 1975. 248 p.

PERFORMANCE SPECIFICATION 7—SPECIFICATIONS AND TEST PROCEDURES FOR HYDROGEN SULFIDE CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1. Applicability and Principle

1.1 *Applicability.* 1.1.1 This specification is to be used for evaluating the acceptability of hydrogen sulfide (H_2S) continuous emission monitoring systems (CEMS's) at the time of or soon after installation and whenever specified in an applicable subpart of the regulations.

1.1.2 This specification is not designed to evaluate the installed CEMS performance over an extended period of time nor does it identify specific calibration techniques and other auxiliary procedures to assess CEMS performance. The source owner or operator, however, is responsible to calibrate, maintain, and operate the CEMS. To evaluate CEMS performance, the Administrator may require, under Section 114 of the Act, the source owner or operator to conduct CEMS performance evaluations at other times besides the initial test. *See* § 60.13(c).

1.1.3 The definitions, installation specifications, test procedures, data reduction procedures for determining calibration drifts (CD) and relative accuracy (RA), and reporting of Performance Specification 2 (PS 2), Sections 2, 3, 5, 6, 8, and 9 apply to this specification.

1.2 Principle. Reference method (RM), CD, and RA tests are conducted to determine that the CEMS conforms to the specification.

2. Performance and Equipment Specifications

2.1 *Instrument zero and span*. This specification is the same as Section 4.1 of PS 2.

2.2 *Calibration drift.* The CEMS calibration must not drift or deviate from the reference value of the calibration gas or reference source by more than 5 percent of the established span value for 6 out of 7 test days (e.g., the established span value is 300 ppm for subpart J fuel gas combustion devices).

2.3 *Relative accuracy.* The RA of the CEMS shall be no greater than 20 percent of the mean value of the RM test data in terms of the units of the emission standard or 10 percent of the applicable standard, whichever is greater.

3. Relative Accuracy Test Procedure

3.1 Sampling Strategy for RM Tests, Correlation of RM and CEMS Data Number of RM Tests, and Calculations. These are the same as that in PS 2, § 7.1, 7.2, 7.3, and 7.5, respectively.

3.2 Reference Methods. Unless otherwise specified in an applicable subpart of the regulation, Method 11 is the RM for this PS.

4. Bibliography

1. U.S. Environmental Protection Agency. Standards of Performance for New Stationary Sources; Appendix B; Performance Specifications 2 and 3 for SO_2, NO_x, CO_2, and O_2 Continuous Emission Monitoring Systems; Final Rule. 48 CFR 23608. Washington, DC, U.S. Government Printing Office. May 25, 1983.

2. U.S. Government Printing Office. Gaseous Continuous Emission Monitoring Systems—Performance Specification Guidelines for SO_2, NO_x, CO_2, O_2, and TRS. U.S. Environmental Protection Agency. Washington, DC, EPA–450/3–82–026. October 1982. 26p.

3. Maines, G.D., W.C. Kelly (Scott Environmental Technology, Inc.), and J.B. Homolya. Evaluation of Monitors for Measuring H_2S in Refinery Gas. Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, NC, Contract No. 68–02–2707. 1978. 60 p.

4. Ferguson, B.B., R.E. Lester (Harmon Engineering and Testing), and W.J. Mitchell. Field Evaluation of Carbon Monoxide and Hydrogen Sulfide Continuous Emission Monitors at an Oil Refinery. Prepared for the U.S. Environmental Protection Agency. Research Triangle

Park, NC. Publication No. EPA–600/4–82–054. August 1982. 100 p.

PERFORMANCE SPECIFICATION 8—PERFORMANCE SPECIFICATIONS FOR VOLATILE ORGANIC COMPOUND CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1. Applicability and Principle

1.1 Applicability.

1.1.1 This specification is to be used for evaluating a continuous emission monitoring system (CEMS) that measures a mixture of volatile organic compounds (VOC's) and generates a single combined response value. The VOC detection principle may be flame ionization (FI), photoionization (PI), nondispersive infrared absorption (NDIR), or any other detection principle that is appropriate for the VOC species present in the emission gases and that meets this performance specification. The performance specification includes procedures to evaluate the acceptability of the CEMS at the time of or soon after its installation and whenever specified in emission regulations or permits. This specification is not designed to evaluate the installed CEMS performance over an extended period of time, nor does it identify specific calibration techniques and other auxiliary procedures to assess the CEMS performance. However, it is the responsibility of the source owner or operator, to calibrate, maintain, and operate the CEMS properly. Under section 114 of the Act, the Administrator may require the operator to evaluate the CEMS performance by conducting CEMS performance evaluations in addition to the initial test. See section 60.13(c).

The definitions, installation and measurement location specifications, test procedures, data reduction procedures, reporting requirements, and bibliography are the same as in PS 2, sections 2, 3, 5, 6, 8, 9, and 10, and also apply to VOC CEMS's under this specification. The performance and equipment specifications and the relative accuracy (RA) test procedures for VOC CEMS do not differ from those for SO_2 and NO_x CEMS, except as noted below.

1.1.2 In most emission circumstances, most VOC monitors can provide only a relative measure of the total mass or volume concentration of a mixture of organic gases, rather than an accurate quantification. This problem is removed when an emission standard is based on a total VOC measurement as obtained with a particular detection principle. In those situations where a true mass or volume VOC concentration is needed, the problem can be mitigated by using the VOC CEMS as a relative indicator of total VOC concentration if statistical analysis indicates that a sufficient margin of compliance exists for this approach to be acceptable. Otherwise, consideration can be given to calibrating the CEMS with a mixture of the same VOC's in the same proportions as they actually occur in the measured source. In those circumstances where only one organic species is present in the source, or where equal incremental amounts of each of the organic species present generate equal CEMS responses, the latter choice can be more easily achieved.

1.2 Principle. Calibration drift and relative accuracy tests are conducted to determine the adherence of the CEMS to specifications given for those items. The performance specifications include criteria for installation and measurement location, equipment and performance, and procedures for testing and data reduction.

2. Performance and Equipment Specifications

2.1 VOC CEMS Selection. When possible, select a VOC CEMS with the detection principle of the reference method specified in the regulation or permit (usually either FI, NDIR, or PI). Otherwise, use knowledge of the source process chemistry, previous emission studies, or gas chromatographic analysis of the source gas to select an appropriate VOC CEMS. Exercise extreme caution in choosing and installing any CEMS in an area with the potential for explosive hazards.

2.2 Data Recorder Scale. Same as section 4.1 of PS 2.

2.3 Calibration Drift. The CEMS calibration must not drift by more than 2.5 percent of the span value.

2.4 CEMS Relative Accuracy. Unless stated otherwise in the regulation or permit, the RA of the CEMS must be no greater than 20 percent of the mean value of the reference method (RM) test data in terms of the units of the emission standard, or 10 percent of the applicable standard, whichever is greater.

3. Relative Accuracy Test Procedure

3.1 Sampling Strategy for RM Tests, Correlation of RM and CEMS Data, Number of RM Tests, and Calculations. Follow PS 2, sections 7.1, 7.2, 7.3, and 7.5, respectively.

3.2 Reference Method. Use the method specified in the applicable regulation or permit, or any approved alternative, as the RM.

PERFORMANCE SPECIFICATION 9—SPECIFICATIONS AND TEST PROCEDURES FOR GAS CHROMATOGRAPHIC CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1. Applicability and Principle

1.1 Applicability. These requirements apply to continuous emission monitoring systems (CEMS) that use gas chromatography (GC) to measure gaseous organic compound emissions. The requirements include procedures intended to evaluate the acceptability of the CEMS at the time of its installation and whenever specified in regulations or permits. Quality assurance procedures for calibrating, maintaining, and operating the CEMS properly at all times are also given in this procedure.

1.2 Principle. Calibration precision, calibration error, and performance audit tests are conducted to determine conformance of the CEMS with these specifications. Daily calibration and maintenance requirements are also specified.

2. Definitions

2.1 Gas Chromatograph (GC). That portion of the system that separates and detects organic analytes and generates an output proportional to the gas concentration. The GC must be temperature controlled.

NOTE: The term ''temperature controlled'' refers to the ability to maintain a certain temperature around the column. Temperature-programmable GC is not required for this performance specification, as long as all other requirements for precision, linearity, and accuracy listed in this performance specification are met. It should be noted that temperature programming a GC will speed up peak elution, thus allowing increased sampling frequency.

2.1.1 Column. An analytical column capable of separating the analytes of interest.

2.1.2 Detector. A detection system capable of detecting and quantifying all analytes of interest.

2.1.3 Integrator. That portion of the system that quantifies the area under a particular sample peak generated by the GC.

2.1.4 Data Recorder. A strip chart recorder, computer, or digital recorder capable of recording all readings within the instrument's calibration range.

2.2 Calibration Precision. The error between triplicate injections of each calibration standard.

3. Installation and Measurement Location Specifications

Install the CEMS in a location where the measurements are representative of the source emissions. Consider other factors, such as ease of access for calibration and maintenance purposes. The location should not be close to air in-leakages. The sampling location should be at least two equivalent duct diameters downstream from the nearest control device, point of pollutant generation, or other point at which a change in the pollutant concentration or emission rate occurs. The location should be at least 0.5 diameter upstream from the exhaust or control device. To calculate equivalent duct diameter, see section 2.1 of Method 1 (40 CFR part 60, appendix A). Sampling locations not conforming to the requirements in this section may be used if necessary upon approval of the Administrator.

4. CEMS Performance and Equipment Specifications

4.1 Presurvey Sample Analysis and GC Selection. Determine the pollutants to be monitored from the applicable regulation or permit and determine the approximate concentration of each pollutant (this information can be based on past compliance test results). Select an appropriate GC configuration to measure the organic compounds. The GC components should include a heated sample injection loop (or other sample introduction systems), separatory column, temperature-controlled oven, and detector. If the source chooses dual column and/or dual detector configurations, each column/detector is considered a separate instrument for the purpose of this performance specification and thus the procedures in this performance specification shall be carried out on each system. If this method is applied in highly explosive areas, caution should be exercised in selecting the equipment and method of installation.

4.2 Sampling System. The sampling system shall be heat traced and maintained at a minimum of 120 °C with no cold spots. All system components shall be heated, including the probe, calibration valve, sample lines, sampling loop (or sample introduction system), GC oven, and the detector block (when appropriate for the type of detector being utilized, e.g., flame ionization detector).

4.3 Calibration Gases. Obtain three concentrations of calibration gases certified by the manufacturer to be accurate to within 2 percent of the value on the label. A gas dilution system may be used to prepare the calibration gases from a high concentration certified standard if the gas dilution system meets the requirements specified in Test Method 205, 40 CFR part 51, appendix M. The performance test specified in Test Method 205 shall be repeated quarterly, and the results of the Method 205 test shall be included in the report. The calibration gas concentration of each target analyte shall be as follows (measured concentration is based on the presurvey concentration determined in section 4.1).

NOTE: If the low level calibration gas concentration falls at or below the limit of detection for the instrument for any target pollutant, a calibration gas with a concentration at 4 to 5 times the limit of detection for the instrument may be substituted for the low-level calibration gas listed in section 4.3.1

4.3.1 Low-level. 40–60 percent of measured concentration.

4.3.2 Mid-level. 90–110 percent of measured concentration.

4.3.3 High-level. 140–160 percent of measured concentration, or select highest expected concentration.

4.4 Performance Audit Gas. A certified EPA audit gas shall be used, when possible. A Protocol 1 gas mixture containing all the target compounds within the calibration range may be used when EPA performance audit materials are not available. The instrument relative error shall be ≤10 percent of the certified value of the audit gas.

4.5 Calibration Error (CE). The CEMS must allow the determination of CE at all three calibration levels. The average CEMS calibration response must not differ by more than 10 percent of calibration gas value at each level after each 24-hour period of the initial test.

4.6 Calibration Precision and Linearity. For each triplicate injection at each concentration level for each target analyte, any one injection shall not deviate more than 5 percent from the average concentration measured at that level. The linear regression curve for each organic compound at all three levels shall have an $r^2 \geq 0.995$ (using Equation 1).

4.7 Measurement Frequency. The sample to be analyzed shall flow continuously through the sampling system. The sampling system time constant (T) shall be ≤5 minutes or the sampling frequency specified in the applicable regulation, whichever is less. Use Equation 3 to determine T. The analytical system shall be capable of measuring the effluent stream at the frequency specified in the appropriate regulation or permit.

5. Performance Specification Test (PST) Periods

5.1 Pretest Preparation Period. Using the procedures described in Method 18 (40 CFR part 60, appendix A), perform initial tests to determine GC conditions that provide good resolution and minimum analysis time for compounds of interest. Resolution interferences that may occur can be eliminated by appropriate GC column and detector choice or by shifting the retention times through changes in the column flow rate and the use of temperature programming.

5.2 7-Day CE Test Period. At the beginning of each 24-hour period, set the initial instrument setpoints by conducting a multipoint calibration for each compound. The multipoint calibration shall meet the requirements in section 4.7. Throughout the 24-hour period, sample and analyze the stack gas at the sampling intervals prescribed in the regulation or permit. At the end of the 24-hour period, inject the three calibration gases for each compound in triplicate and determine the average instrument response. Determine the CE for each pollutant at each level using the equation in section 6.2. Each CE shall be ≤10 percent. Repeat this procedure six more times for a total of 7 consecutive days.

5.3 Performance Audit Test Periods. Conduct the performance audit once during the initial 7-day CE test and quarterly thereafter. Sample and analyze the EPA audit gas(es) (or the Protocol 1 gas mixture if an EPA audit gas is not available) three times. Calculate the average instrument response. Report the audit results as part of the reporting requirements in the appropriate regulation or permit (if using a Protocol 1 gas mixture, report the certified cylinder concentration of each pollutant).

6. Equations

6.1 Coefficient of Determination. Calculate r^2 using linear regression analysis and the average concentrations obtained at three calibration points as shown in Equation 1.

ER15DE94.000

Where:

r^2=Coefficient of determination.
n=Number of measurement points.
x=CEMS response.
y=Actual value of calibration standard.

6.2 Calibration Error Determination. Determine the percent calibration error (CE) at each concentration for each pollutant using the following equation.

ER15DE94.001

where:

C_m=average instrument response, ppm.
C_a=cylinder gas value, ppm.

6.3 Sampling System Time Constant (T).

ER15DE94.002

where:

F=Flow rate of stack gas through sampling system, in liters/min.
V=Sample system volume, in Liters, which is the volume inside the sample probe and tubing leading from the stack to the sampling loop.

7. Daily Calibration

7.1 Initial Multipoint Calibration. After initial startup of the GC, after routine maintenance or repair, or at least once per month, conduct a multipoint calibration of the GC for each target analyte. The multipoint calibration for each analyte shall meet the requirements in section 4.7.

7.2 Daily Calibration. Once every 24 hours, analyze the mid-level calibration standard for each analyte in triplicate. Calculate the average instrument response for each analyte. The average instrument response shall not vary more than 10 percent from the certified concentration value of the cylinder for each analyte. If the difference between the analyzer response and the cylinder concentration for any target compound is greater than 10 percent, immediately take corrective action on the instrument if necessary, and conduct an initial multipoint calibration as described in section 7.1.

8. Reporting

Follow the reporting requirements of the applicable regulation or permit. If the reporting requirements include the results of this performance specification, summarize in tabular form the results of the CE tests. Include all data sheets, calculations, CEMS data records, performance audit results, and calibration gas concentrations and certifications.

[48 FR 13327, Mar. 30, 1983 and 48 FR 23611, May 25, 1983, as amended at 48 FR 32986, July 20, 1983; 51 FR 31701, Aug. 5, 1985; 52 FR 17556, May 11, 1987; 52 FR 30675, Aug. 18, 1987; 52 FR 34650, Sept. 14, 1987; 53 FR 7515, Mar. 9, 1988; 53 FR 41335, Oct. 21, 1988; 55 FR 18876, May 7, 1990; 55 FR 40178, Oct. 2, 1990; 55 FR 47474, Nov. 14, 1990; 56 FR 5526, Feb. 11, 1991; 59 FR 64593, Dec. 15, 1994]